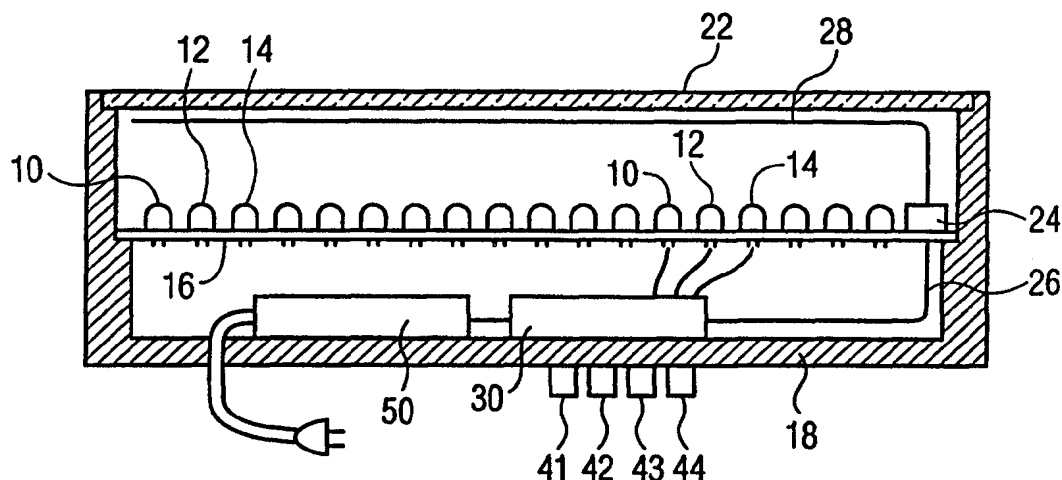




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> : <b>G01J 3/50</b>	<b>A1</b>	(11) International Publication Number: <b>WO 00/37904</b> (43) International Publication Date: 29 June 2000 (29.06.00)
(21) International Application Number: PCT/EP99/09592 (22) International Filing Date: 2 December 1999 (02.12.99) (30) Priority Data: 09/216,262                      18 December 1998 (18.12.98)      US (71) Applicant: KONINKLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL). (72) Inventors: PASHLEY, Michael, D.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). MARSHALL, Thomas, M.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). (74) Agent: ROLFES, Johannes, G., A.; Internationaal Octrooibu- reau B.V., Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).		(81) Designated States: CN, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published <i>With international search report.</i>

(54) Title: LED LUMINAIRE



## (57) Abstract

A white light emitting luminaire includes a plurality of LEDs (10, 12, 14) in each of the colors red, green, and blue with a separate power supply for each color and a photodiode (24) arranged to measure the light output of all the LEDs. The light output of each color is measured by an electronic control circuit (30) which turns off the LEDs for the colors not being measured in a sequence of time pulses. The measured light output for each color is compared to a desired output, which may be determined by user inputs, and corrections to the current for each color are made accordingly.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

Led luminaire.

The invention relates to a luminaire with an array red, green and blue light emitting diodes (LEDs), and more particularly to a white light emitting luminaire with a control system for adjusting the individual components to maintain a desired color balance (chromaticity).

5 U.S. Patent No. 5,301,090 discloses an LED luminaire having an array of LEDs including a plurality of LEDs in each of the colors red, green, and blue. The LEDs for each color are wired in parallel and provided with a separate power supply, and a diffusion screen is provided over the array. The chromaticity of the assembly is manually controlled by three knobs for the respective colors; automatic control is not mentioned.

10 LEDs are semiconductor based; for a given drive current, light output varies from chip to chip, and also varies over the life of each chip. Light output also varies inversely with temperature, but not uniformly for each color. Finally, in a block of LEDs of a given color, the light output will vary if one or more of the LEDs fails. Given all the factors which can affect the color balance of any array of LEDs, it would be desirable to automatically  
15 monitor and regulate the color balance, especially in a white-light emitting luminaire.

It is known to control current to an array of LEDs in a given color based on temperature, for example in a traffic light. This scheme would be cumbersome in a luminaire having LEDs in a plurality of colors, because the temperature (and therefore the light intensity) does not vary uniformly for the various colors.

20 It would be desirable to automatically control the chromaticity of a white light emitting luminaire, without regard to the factors which cause the light outputs of the individual colors to vary.

It would further be desirable to automatically control the chromaticity without resorting to a spectrally resolving light measuring system such as a photodiode and filter for  
25 each of the respective colors.

According to the invention, the combined light output (chromaticity) of a white light emitting LED luminaire is electronically controlled based on measurements by a single

photodiode arranged to measure the light outputs of all the LEDs in the array. This is accomplished by measuring the light output of the LEDs in each color separately in a sequence of time pulses. For an array of red, green, and blue LEDs, there are three time pulses in a measuring sequence. During each time pulse, the current for the colors not being measured is  
5 turned off. The response time of a typical photodiode is extremely short, so the measuring sequence can be performed in a sufficiently short time that an observer will not detect it (e.g. 10 ms).

Measured light outputs for the colors are compared to desired outputs, which may be set by user controls, and changes to the power supply for the color blocks are made as  
10 necessary. Chromaticity is thus automatically controlled without regard to the factors which may cause it to change. The user inputs permit varying the desired chromaticity to either warm white (more red output) or cool white (more blue output).

In order to best compensate for temperature dependent changes during a warm-up phase, the electronic control circuitry may undertake the measuring sequence more  
15 frequently during warm-up. Less frequent measurements are sufficient to compensate for long term changes in the LEDs after a stable operating temperature is reached.

Where the LEDs in each color are wired in parallel, the failure of an LED can be automatically compensated by varying the current to the remaining LEDs during the next measuring sequence.

20 These and additional advantages of the invention will be apparent from the drawings and description which follows.

Figure 1 is a cross-sectional view of a luminaire according to the invention,  
25 with an optical fiber light pick-up;

Figure 2 is a schematic diagram of the luminaire;

Figure 3 is a diagram of the logic sequence for the controller; and

Figure 4 is a timing diagram for the optical feedback system.

30 The Figures are not drawn to scale. In general, like reference numerals refer to like parts in the Figures.

Referring to Figure 1, an LED luminaire according to the invention includes a two dimensional array of LEDs 10, 12, 14 including a plurality of LEDs in each of a plurality of colors. In the present case the array includes red LEDs 10, green LEDs 12, and blue LEDs

14 mounted on a wired substrate 16 in a housing 18. The LEDs are arranged so that the overall light output will be white; a diffuser 22 mounted on the housing 18 is provided to enhance mixing. LEDs in additional colors, such as amber, may be used to enhance the mixing options. The mixing optics may include means other than a diffuser.

5                   A single photodiode 24 is arranged to sense the light intensity of all the LEDs in the array. In Figure 1 an optical fiber extending along the length of the housing 18 sends light to the photodiode 24, which generates corresponding current signals for controller 30 via feedback line 26. For small arrays the photodiode may be arranged to sense the light outputs directly. Large numbers of LEDs may be divided into arrays with a photodiode for each array,  
10 instead of the optical fiber arrangement depicted in Figure 1.

Referring also to Figure 2, the controller 30 translates the feedback from the photodiode 24 into color point measurements which are compared with desired settings provided via user inputs 40. Based on the comparison, the controller 30 decides whether the desired color balance is present, and accordingly signals the current regulators 11, 13, 15 for  
15 the respective diodes 10, 12, 14. A power input from the AC converter 50 is thus translated into current outputs which control the light intensity for the respective colors red, green, and blue to obtain the desired color balance. The diodes for each color of the array are kept at common potential by wiring on the substrate 16. User controls for the desired settings include inputs 41, 42, 43 for the respective colors, and a dimmer 44 which controls overall intensity of  
20 the resulting white light.

Figure 3 depicts the control logic for the luminaire in a diagram. When the lamp is turned on (31), power is provided to the LEDs and a measuring sequence is initiated (32). Color point measurements are compared (33) with desired settings which are stored (34) pursuant to user adjustment (35). Based on this comparison, it is determined (36) whether  
25 color adjustments are necessary, and if so, adjustments are made (37) and the measuring sequence is repeated (32). If it is determined that color adjustments are not necessary (36), the controller will wait for a predetermined measuring interval (38) before repeating the measuring sequence (32).

Figure 4 is a timing diagram illustrating the control logic, which is executed  
30 while the luminaire is turned on. The topmost of the four traces is a measuring signal consisting of a series of three pulses (the measuring sequence), separated by a span of time (the measuring interval). During the first pulse, the green and blue LEDs are turned off and so the photodiode can measure the light intensity of the red LEDs; during the second pulse the red and blue LEDs are turned off so that the photodiode can measure the light intensity of the

green LEDs; during the third pulse the red and green LEDs are turned off so that the photodiode can measure the light intensity of the blue LEDs. The control electronics then compares the measured intensities with the desired intensities and adjusts the current to one or more groups of LEDs as may be necessary.

5                   The response time of a typical photodiode is extremely short, and each pulse can be so short that an observer will not detect it, e.g. 1.0 ms. Thus a measuring sequence can be performed during normal operation of the luminaire. The length of the measuring interval depends on how quickly the light output varies. This depends, for example, on how quickly the temperature of the LEDs is changing. It could range from every minute to every few hours;  
10 the control logic can be programmed for frequent measurements shortly after start-up, followed by less frequent measurements when stable operating temperature is reached.

                  It is possible for the luminaire to include more than one string of LEDs in each color, and to measure the outputs of the strings individually. For example, with two strings in each of three colors, a measuring sequence would have six pulses. In every case it is preferable  
15 to adjust the color balance based on all of the measurements in a sequence, rather than adjusting the individual colors based solely on the corresponding light output.

                  The foregoing is exemplary and not intended to limit the scope of the claims which follow.

## CLAIMS:

1. Luminaire comprising  
an array of LEDs comprising at least one LEDs (10,12,14) in each of a plurality  
of colors,  
means for supplying electrical current to said LEDs in each said color, whereby  
5 said LEDs (10,12,14) in each said color have a light output, and the array has a combined light  
output when current is supplied to all of the LEDs in the array,  
a photodiode (24) arranged to measure the light outputs of all the LEDs in the  
array,  
means (30) for selectively turning off the electrical current to said LEDs  
10 (10,12,14) so that the photodiode (24) measures the light output for each color separately in a  
sequence of time pulses,  
means for comparing the measured light output for each color to a respective  
desired light output for each color, and  
means (30) for adjusting the electrical current to the LEDs in each color based  
15 on said comparison, whereby a desired combined light output may be achieved using only a  
single photodiode for the array.
2. Luminaire as in claim 1 further comprising an optical fiber (28) arranged to  
receive light from all LEDs (10,12,14) in the array, said optical fiber (28) being connected to  
20 said photodiode (24).
3. Luminaire as in claim 1 further comprising user input controls (41,42,43) for  
setting the desired light outputs.
- 25 4. Luminaire as in claim 1 wherein said array of LEDs comprises LEDs (10,12,14)  
in each of the colors red, green, and blue, said LEDs being arranged so that the combined light  
output is white.

5. Luminaire as in claim 4 further comprising mixing optics (22) for mixing the colors to obtain a uniform white light.

6. Method for adjusting the color balance of an LED luminaire, said method

5 comprising

providing an array of LEDs (10,12,14) comprising at least one LED in each of a plurality of colors,

supplying electrical current (31) to said LEDs (10,12,14) in each said color, whereby said LEDs in each said color have a light output, and the array has a combined light  
10 output when current is supplied to all of the LEDs in the array,

providing a photodiode (24) arranged to measure the light outputs of all the LEDs in the array,

sequentially measuring the light outputs (32) of the LEDs (10,12,14) for each said color using said photodiode (24),

15 comparing the measured light output (33) for each color to a respective desired light output for each color, and

adjusting the electrical current (37) to the LEDs (10,12,14) in each color based on said comparison.

20 7. Method as in claim 6 wherein said sequentially measuring (32) comprises

providing electrical current to said LEDs in each said color separately in a measuring sequence having one time pulse for each color, and

measuring the light output for one of said colors during each said time pulse.

25 8. Method as in claim 7 wherein said providing electrical current comprises

turning off the electrical current for all but the color being measured during each said time pulse, and

providing electrical current to all of said LEDs in the array between said pulses and during a measuring interval separating the measuring sequences.



1/3

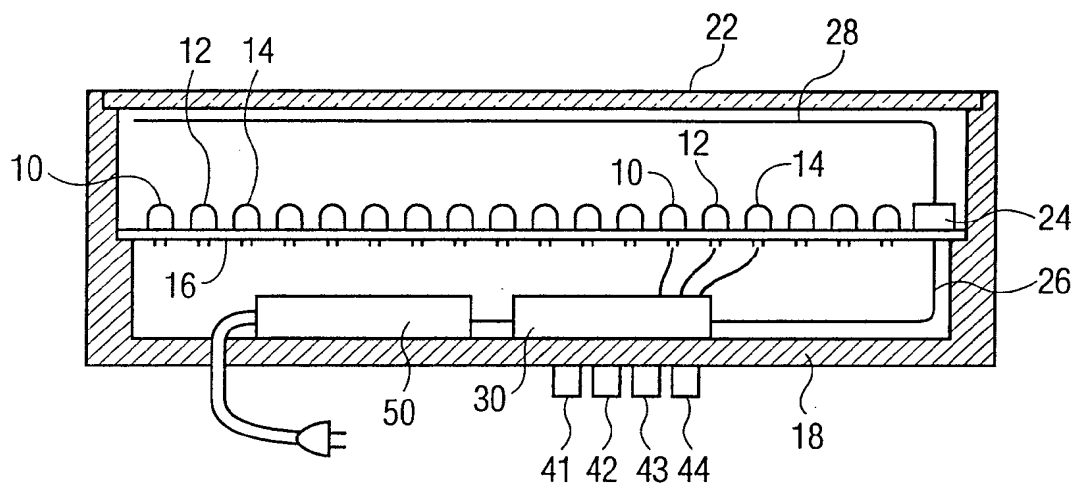


FIG. 1

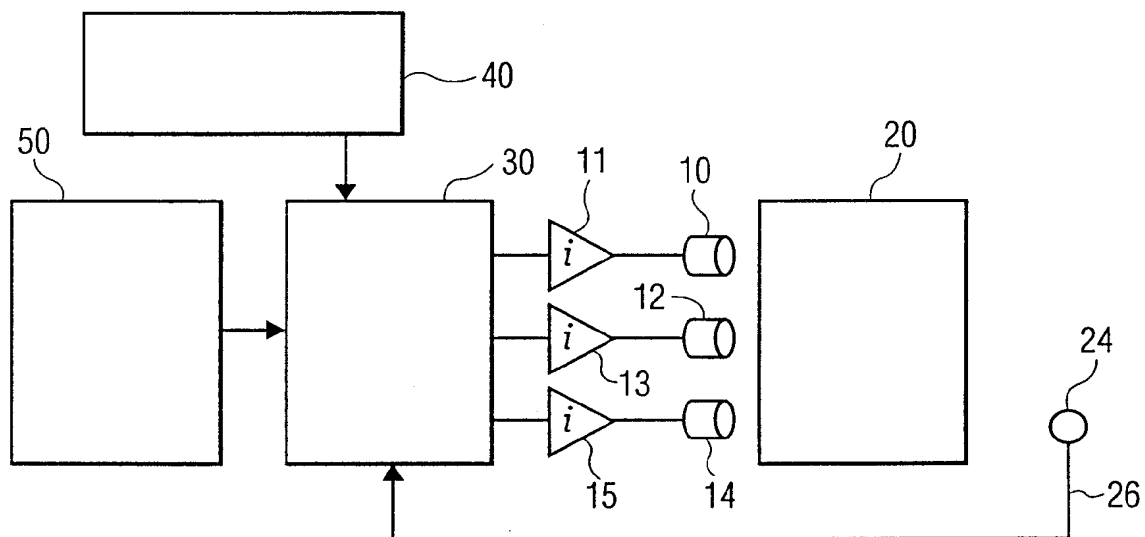


FIG. 2

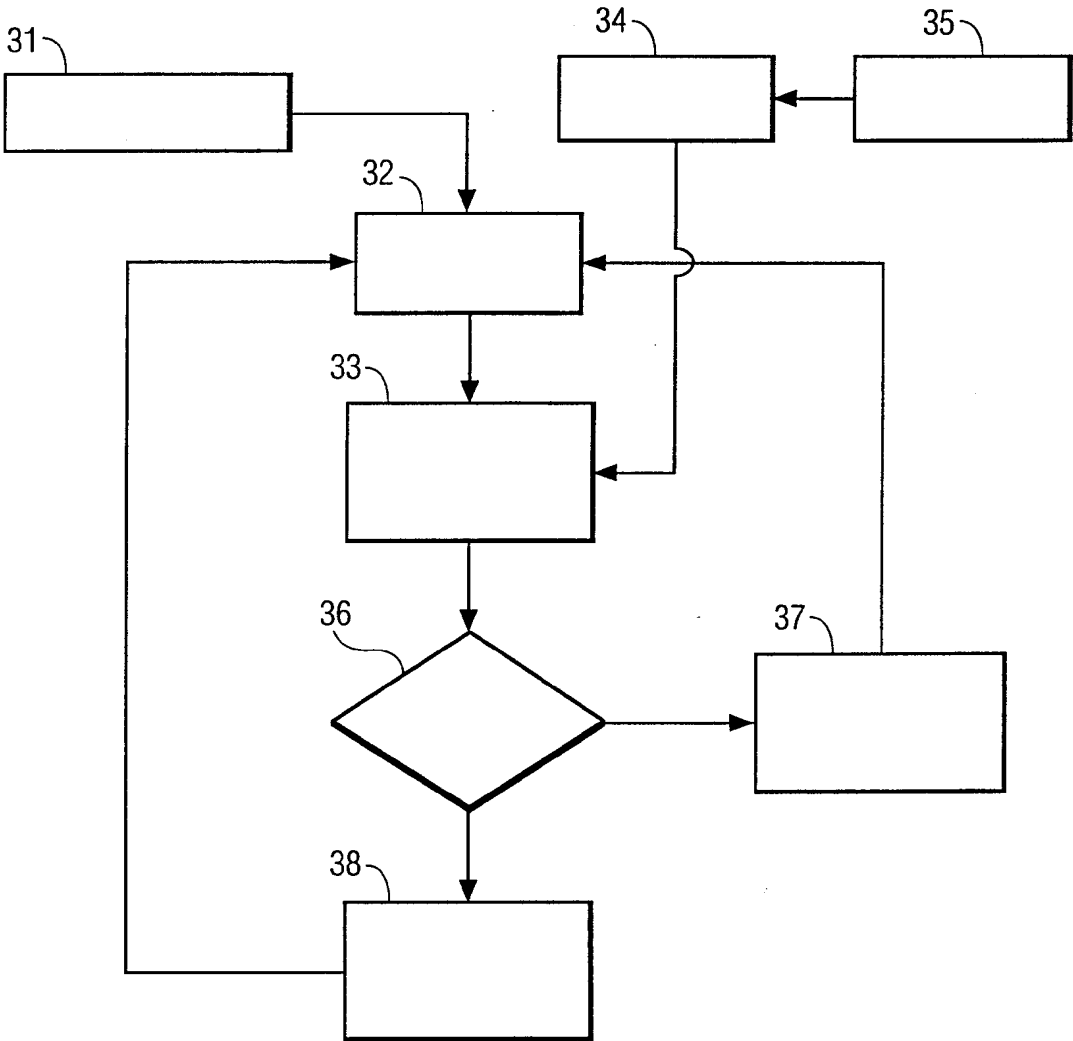


FIG. 3

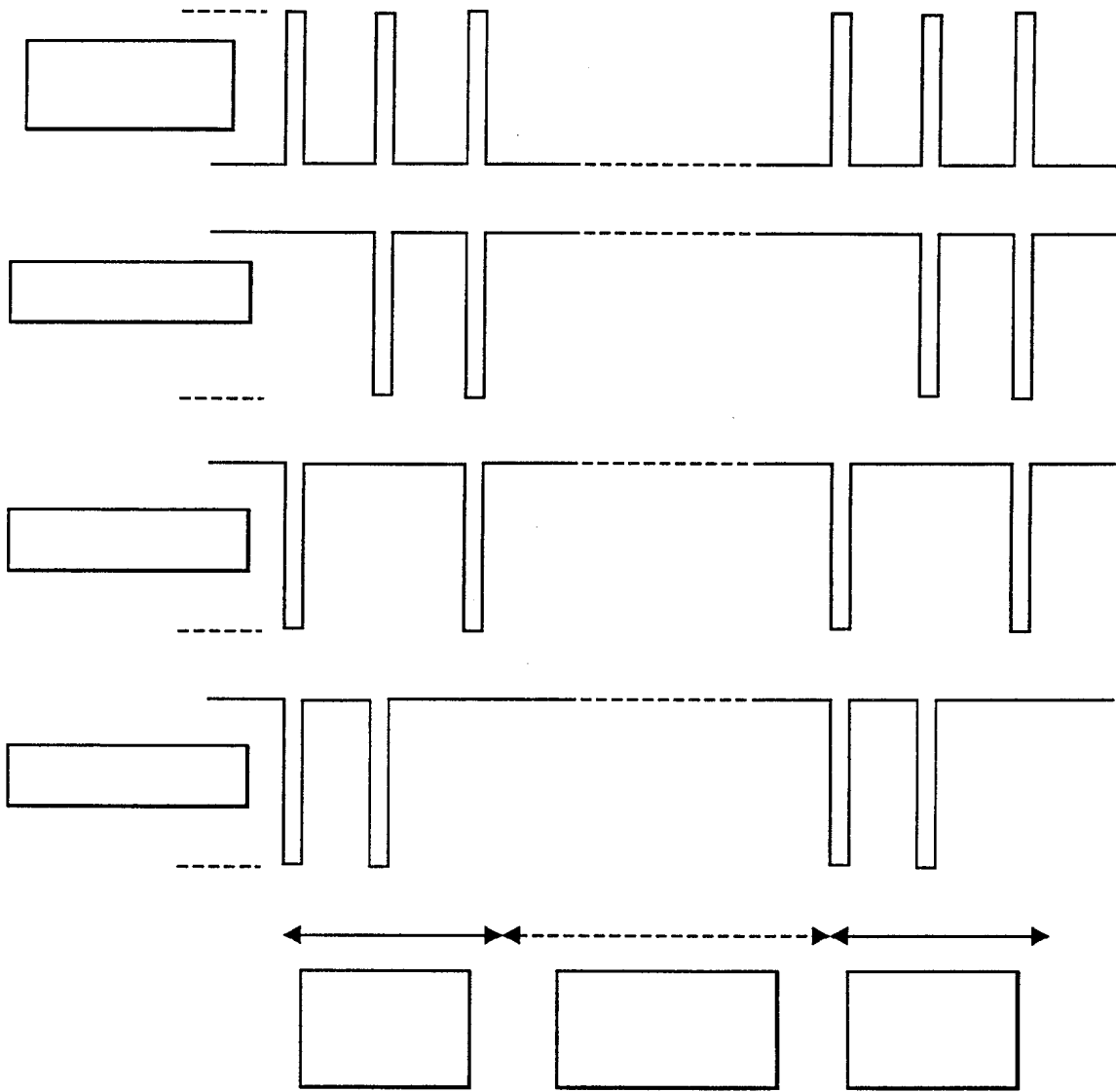


FIG. 4

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 99/09592

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G01J3/50

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 01, 29 January 1999 (1999-01-29) & JP 10 281873 A (ROHM CO LTD), 23 October 1998 (1998-10-23) abstract	1,6
Y	PATENT ABSTRACTS OF JAPAN vol. 010, no. 080 (P-441), 29 March 1986 (1986-03-29) & JP 60 216336 A (CANON KK), 29 October 1985 (1985-10-29) abstract	1,6
A	WO 97 09589 A (LUCAS IND PLC ;HAZELDEN ROGER JOHN (GB); HAWKER STEPHEN DAVID (GB)) 13 March 1997 (1997-03-13) the whole document	1-8
-/--		

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

8 March 2000

Date of mailing of the international search report

17/03/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3018

Authorized officer

VILLAFUERTE ABR., L

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 99/09592

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	EP 0 921 568 A (MATSUSHITA ELECTRIC WORKS LTD) 9 June 1999 (1999-06-09) the whole document _____	1-8

# INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/EP 99/09592

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 10281873 A	23-10-1998	NONE	
JP 60216336 A	29-10-1985	NONE	
WO 9709589 A	13-03-1997	NONE	
EP 0921568 A	09-06-1999	JP 11163412 A	18-06-1999
		JP 11162231 A	18-06-1999
		JP 11162232 A	18-06-1999